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Full Length Research Paper

Allelopathy as expressed by *Mucuna pruriens* and the possibility for weed management

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A twelve-week study was undergone to identify selective effects of *Mucuna* on companion crop plant and to screen *Mucuna* for capacity to suppress weeds. A 10% (v/w) contamination with Nigerian Bonny light crude oil was simulated for stress tolerance assessment. *Mucuna pruriens* supported revegetation, soil and water conservation and also contains potentially toxic BTEX and PAHs that are not phytotoxic to itself but suppressed the growth of *Sphenostylis stenocarpa* and inhibited the growth of weeds. The detrimental influence on crop plant could be linked to the interactions between soil microorganisms and plants at the rhizophere and this conferred competitive advantage on *Mucuna*. Physiological and environmental stress induced by hydrocarbon contamination, affected the growth performance of *Mucuna* and decreased the amount of these toxic compounds released. Comparable amount of toxic hydrocarbons were found in *Mucuna* grown in uncontaminated treatments confirming its natural composition. Growth indices measured as plant height, leaf area and dry weight, confirmed allelopathic suppression on crops. Allelopathic chemicals persisted in some neighbouring plants as those planted in succession. Although produced allelochemicals acted as herbicides, it may also have undesirable effects on non-target species thus the need for prior ecological studies.

Key words: Allelopathy, contamination, germination, growth, interplant, *Mucuna*, toxicity, weed.

INTRODUCTION

Allelopathy refers to the beneficial or harmful effects on one plant, both crop and weeds species through the release from plant parts by leaching, root exudation, volatilization, residue decomposition and other processes in both natural and artificial systems (Ferguson and Rathinasabapathi, 2009). Allelopathy is clearly distin-guished from competition: in allelopathy, a chemical is introduced by the plant into the environment, whereas in competition the plant removes or reduces such environmental components as minerals, water, space, gas exchange and light. In the field, both allelopathy and competition usually act simultaneously (McGraw, 2002). Plant-derived smoke may be another vehicle by which allelochemicals can be introduced into the environment (Marcello et al., 2007). First widely studied in forestry systems, allelopathy can affect many aspects of plant ecology including occurrence, growth succession, the structure of plant communities, dominance, diversity and plant productivity (Ferguson and Rathinasabapathi, 2009; Thelen et al, 2005). Allelopathic inhibition is complex and can involve the interaction of different classes of chemicals like phenolic compounds, terpenoids, alkaloids, steroids, carbohydrates, and amino acids, with mixtures of different compounds sometimes having some allelopathic effect than individual compounds alone. Allelopathic interactions are also thought to be an important factor in the success of many invasive plants (Khanh et al., 2007; Halsey, 2004). For specific examples, see Spotted Knapweed (*Centaurea maculosa*), Garlic Mustard (*Alliaria petiolata*) and Nutsedge (Khanh et al., 2007). *Mucuna* (*Mucuna pruriens* var. *pruriens*) seeds contain high concentrations of levodopa, a direct precursor of the neurotransmitter dopamine that has a profound influence on sexual function (Giuliano and Allard, 2001). The hairs lining seed pods contain 5-hydroxytryptamine (serotonin) that causes severe itches (erythema) and the chemical compound responsible for the itch is a protein, mucunain, (Giuliano and Allard, 2001). Published researches have reported allelopathy in walnut, leucaena lantana, sour orange, red maple, red cedar, sweet bay, swamp chestnut oak, eucalyptus, neem, chaste tree,

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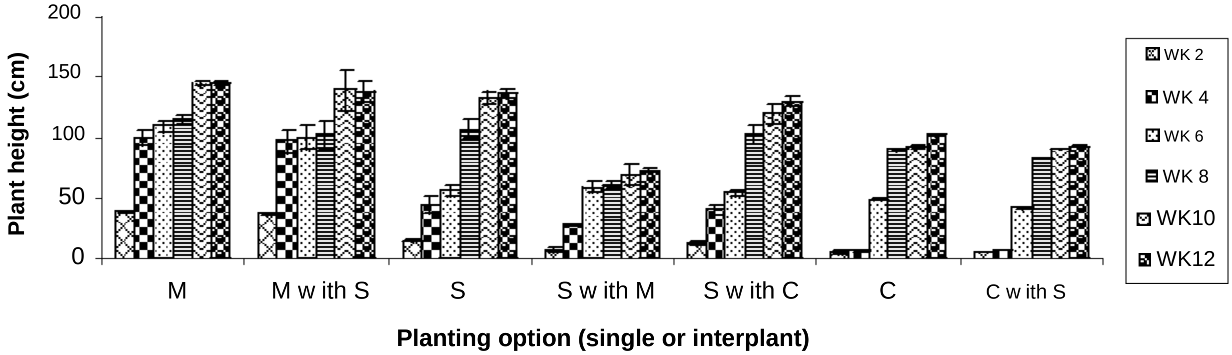

Figure 1. Plant height (cm) ± SE with time (weeks) - UNCON.

mango, tree of heaven, rye, wheat and broccoli, however, there is no such documentary on *Mucuna* , which has not benefited from such researches in this regard. *Centrosema pubescen* Benth, commonly known as Centro plant has good resistance to stressful conditions and experiences die-back from its shoot (Parbery, 1967). Petroleum is a complex mixture of hydrocarbons that form from the partial decomposition of biogenic materials (Overton et al., 1994). The severity of oil spills on plant and microbial life depends on the type of hydrocarbons, toxic metals, amount of oil involved, type of habitat, degree of weathering, sensitivity of affected organisms, topography of the land and adequacy of response (Benka-Coker and Ekundayo, 1995). This study therefore investigates the potentials of *Mucuna* plants for allelopathy and its utilization in agronomic management practice as well as performance under stress (hydrocarbon contamination).

MATERIALS AND METHODS

Random sampling technique in a quadrat design (100 by 100 cm) was employed to locate seven sampling points and surface 0 - 15 cm (Odu, 1972) sandy loam soil from an agricultural grassland lying fallow (with no history of pollution) located in Choba East West, a typical Niger Delta Region, Rivers State of Nigeria was collected. All soil samples were air- dried, gently crushed, sieved to < 2 mm, for basic characterization analysis (Table 4) and collection was done using a stainless steel hand auger. Two kilogram soil was measured into a 45 x 45 cm polyethylene bag in triplicates with 3 - 4 holes per bag for free drain and adequate aeration. A 10 % (v/w) contamination with Nigerian Bonny light crude oil for stress tolerance assessment was done by top-dressing and allowed for 2 weeks before planting. Scarified and viable 10 seeds of *Mucuna*, *Sphenostylis stenocarpa*, and Centro were seeded singly or as interplant into different soil groups and thinned down to three for singles and 4 for interplant (germination tests were conducted for viability and efficiencies). Co- germination of *Mucuna* seeds with *S. stenocarpa* seeds and those of Centro seeds with *S. stenocarpa* seeds were set up for comparison. The three plants were grown in crude oil-contaminated and un-contaminated soil and the experiment was set up during the rainy season (mid-April 2008). Plant growth indices were measured biweekly and harvested at 6 and 12 weeks for comparison. Harvested plants were washed thoroughly with deionized water and sun-dried to constant weight while measuring the shoot dry weight. Leaves were finely ground and their PAH (polycyclic aromatic hydrocarbons) and BTEX (benzene, toluene, ethylbenzene and xylene) levels were determined with gas chromatograph (GC - FID) with GC recorder interfaced with HP Pentium III MMX Computer, ATI Unicam 610 series. Germination of *S. stenocarpa* and Mucuna seeds in soil from which Mucuna plants were harvested after 12 weeks of growth were tried simultaneously for further investigations.

Statistical analysis

Statistical package for social sciences for windows version 10.0 (SPSS Inc., Chicago, IL) was used to perform one - or two - way analysis of variance and the Pearson correlation. Pairs of treatment means were compared for significant differences using least significant difference (LSD) at the 5% level.

RESULTS AND DISCUSSION

Co-germination of Mucuna seeds with *S. stenocarpa* seeds revealed no significant inhibition on germination but became marked with seedling emergence and growth (Figures 1 and 2). However, co-germination of Centro seeds with *S. stenocarpa* seeds gave no marked variation at germination as well as growth. Centro plants were introduced for comparison. Centro and *S. stenocarpa* plants competed favourably with weeds but no weed was found growing with Mucuna throughout the study period. Mucuna plants grown in both contaminated and uncontaminated soil demonstrated significant allelopathic effect on the emergence, rate of growth, final height, or average vegetative dry weight of *S. stenocarpa* plants at the 5% confidence level. Transport of allelopathic compounds synthesized by Mucuna was by natural method of dissemination namely soil and rain as recorded by Ferreira and Janick (2004). Further germination of *S. stenocarpa* seeds in soil from which Mucuna was harvested after 12 weeks of growth proved abortive but same recorded success for *Mucuna* seeds. This pot trial confirmed laboratory results and is in conformity with the work by Ferguson and Rathinasabapathi (2009). Hydrocarbons stress reduced allelochemicals released thereby exposing *Mucuna* to

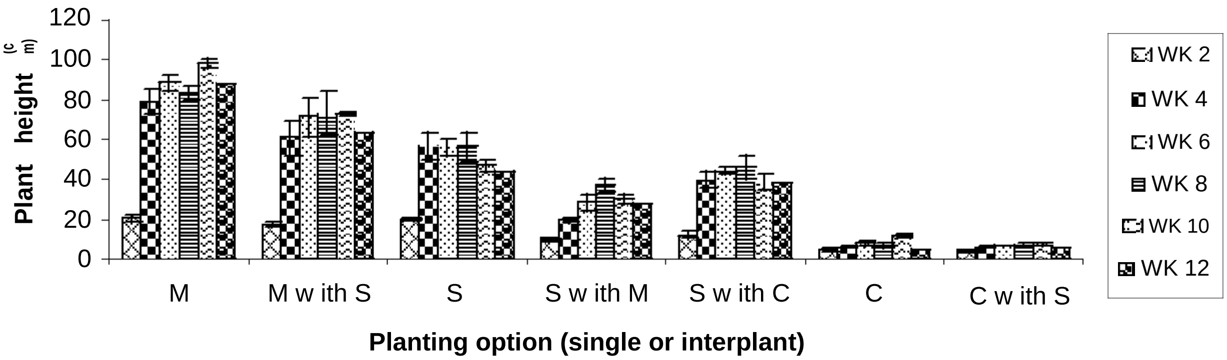

Figure 2. Plant height (cm) ± SE with time (weeks) - CON.

Table 1. PAHs and BTEX level (mg/kg) of plants (leaves) at 12WAG.

Plant leaves	PAHs UNCON	PAHs CON	BTEX UNCON	BTEX CON
M alone	2.89m ± 0.15	18.48k ± 6.01	0.42n ± 0.01	1.75o ± 0.11
M with S	2.80m ± 0.09	17.51k ± 4.01	0.41n ± 0.02	1.69o ± 0.51
S alone	< 0.001	0.002 g ± 0.01	< 0.001	< 0.001
S with M	< 0.001	0.003 h±0.01	< 0.001	< 0.001
C alone	< 0.001	< 0.001	< 0.001	< 0.001
C with S	< 0.001	< 0.001	< 0.001	< 0.001
S with C	< 0.001	< 0.001	< 0.001	< 0.001

Values denote mean ± standard error (n = 3). Means in the same column having the same letters are not significantly different at p 0.05. PRE-P = contaminated soil with crude oil after two weeks and before planting. PAHs = Polycyclic aromatic hydrocarbons; BTEX = benzene, toluene, ethylbenzene and xylene; CON = contaminated group; UNCON: uncontaminated group; C = Centro, S = *Sphenostylis stenocarpa*; M = *Mucuna*; M with S = *Mucuna* intercropped with S, S with M = *Sphenostylis stenocarpa* intercropped with M; C with S = Centro intercropped with S; S with C = *Sphenostylis stenocarpa* intercropped with Centro; 12WAG = 12 weeks after germination.

phytotoxicity that eventually led to chlorosis, scaly leaves production, burns and tiny stems production. Apart from its hydrocarbon - extraction potentials over Centro and *S. stenocarpa*, Mucuna was more resistance than *S. stenocarpa* to hydrocarbon stress (Table 3 and all Figures). Mucuna bioaccumulated 18.48 and 1.75 mg/kg PAH and BTEX respectively into their leaf tissue as against 0.002 mg/kg and values below detectable limits of the analytical instrument used for *C. pubescen* and *S. stenocarpa* respectively. Growth was influenced grossly by environmental stress - contamination especially after week 8 for Centro and *S. stenocarpa* plants (Figure 2). Mucuna showed no statistically significant difference between its growth alone and that of intercrop with *S. stenocarpa* (Table 1). There was a suppressed growth of *S. stenocarpa* intercropped with Mucuna as compared with same plant intercropped with Centro plants. *S. stenocarpa* and *C. pubescen* competed favourably with grasses with/ without contamination. This is in agreement with the findings of Kruse et al. (2000) . Allelopathic interaction between *S. stenocarpa* and *M. pruriens* was also evident in marked leaf area reduction as compared with those of *S. stenocarpa* and Centro plants (Figure 3). Leaf area reduced with time after the onset of growth for all groups under hydrocarbon stress (Figure 4). Table 2 indicates a linear relationship between allelopathy and hydrocarbon degradation. Also, for *S. stenocarpa*, produced dry weight indicated significant weight loss with Mucuna compared to interaction with Centro (Table 3). Dry weight of 1.58 g in *S. stenocarpa* was reduced to 1.06 g when intercropped with *Mucuna* plants and was significantly poor compared to 1.51 g obtained with Centro plants. *M. pruriens* var. utilis (the non- stinging variety) as against M. pruriens var. pruriens (which causes severe itching) could be potentially used to control weeds either as a rotational sequence, or when left as a residue or mulch, especially in low-till systems, thereby reducing application rates of synthetic herbicide. Nutrient amendments could enhance growth where *M. pruriens* is planted as weed control and is therefore recommended. Also, allelochemistry may therefore enlist Mucuna plants for herbicide development. Generally, allelopathic *Mucuna* evident in suppressed growth of *S. stenocarpa* intercropped with it by growth indices analysis, as compared with such interaction between *C. pubescen* and *S. stenocarpa* was interestingly striking and the stress due to simulated oil spill further supported allelopathy (Figure 2). Root exudates of *Mucuna* plants

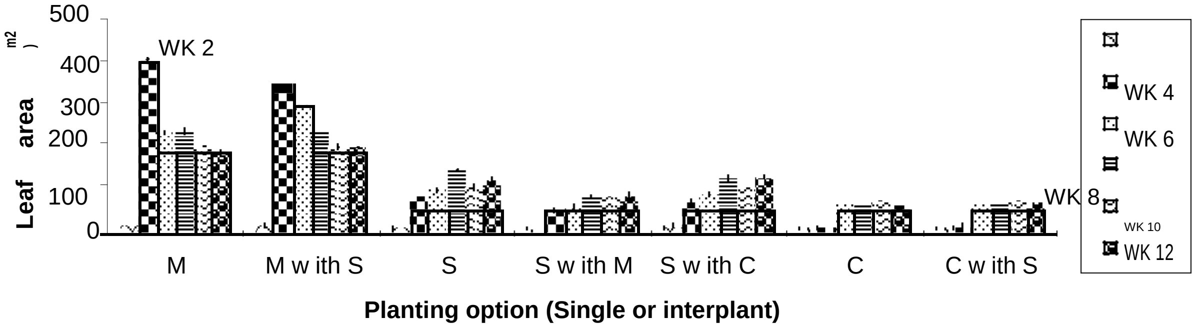

Figure 3. Leaf area (cm^2) ± SE with time (weeks) - UNCON.

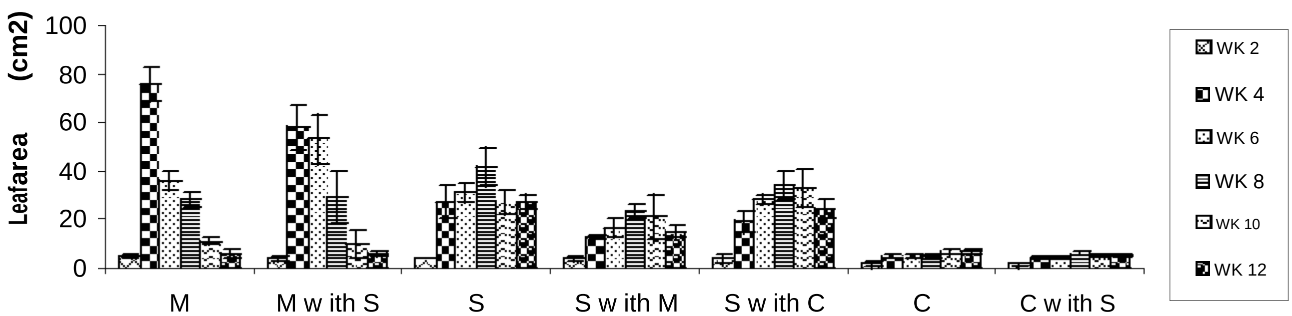

Figure 4. Leaf area (cm^2) ± SE with time (weeks) - CON.

Table 2. PAHs and BTEX level (mg/kg) of soils at 12WAG.

Soil	PAHs UNCON	PAHs CON	BTEX UNCON	BTEX CON
M alone	3.18a ± 0.03	21.48h ± 0.03	1.02b ± 0.31	4.20e ± 0.04
M with S	1.26a ± 0.02	21.01ih ± 0.03	0.08b ± 0.22	4.14e ± 0.04
S alone	< 0.001	31.90d ± 0.22	< 0.001	6.40f ± 0.02
S with M	1.26a ± 0.02	21.01ih ± 0.03	0.08b ± 0.22	4.14e ± 0.04
C alone	< 0.001	28.53h ± 0.02	< 0.001	6.06j ± 0.01
C with S	< 0.001	28.74h a ± 0.01	< 0.001	6.01j ± 0.10
S with C	< 0.001	28.74h a ± 0.01	< 0.001	6.01j ± 0.10

BTEX in PRE-P = 10.00 ± 3.00 and PAHs in PRE-P = 43.13 ± 6.01.
Values denote mean ± standard error (n = 3). Means in the same column having the same letters are not significantly different at p 0.05. PRE-P = contaminated soil with crude oil after two weeks and before planting; PAHs = polycyclic aromatic hydrocarbons; BTEX = benzene, toluene, ethylbenzene and xylene; CON = contaminated group; UNCON: uncontaminated group; C = Centro, S = *S. stenocarpa*; M = *Mucuna*; M with S = *Mucuna* intercropped with S, S with M = *S. stenocarpa* intercropped with M; C with S = Centro intercropped with S; S with C = *S. stenocarpa* intercropped with Centro; 12WAG = 12 weeks after germination.

have no significant effect (Figures 1 and 2) on the early growth of *S. stenocarpa*. Significance was found, however, in the last phase of the experiments. Volatile growth inhibitors produced by aromatic shrubs (Muller et al., 1964) such as *M. pruriens* could be seen in forms of toxic hydrocarbons (Table 1, columns 1 and 3). The high tolerance of Mucuna to the potentially toxic compounds released by it constitutes a major finding in this study. Also, Mucuna extracted well over 30% of soil hydrocarbon content into its harvestable portion (leaf) and thus may be a potential candidate for phytoextraction of hydrocarbon contaminants from oil spill soils and at soil clean-up generally (Table 2). This is in conformity with the findings of Nwaichi et al. (2009).

Conclusion

M. pruriens var. utilis (the non-stinging variety) as against M. pruriens var. pruriens (which causes severe itching) could be potentially used to control weeds either as a rotational sequence, or when left as a residue or mulch,

Table 3. Dry weight (g) of species studied under various treatments at 12 WAG.

Species	M	M with S	S	S with M	S with C	C with S	C
UNCON	2.93 ± 0.5	2.75 ± 0.45	1.58 ± 0.9	1.06 ± 0.66	1.51 ± 0.9	1.22 ± 0.5	1.29 ± 0.4
CON	1.69 ± 0.06	1.36 ± 0.03	0.47 ± 0.06	0.23 ± 0.01	0.44 ± 0.12	0.58 ± 0.01	0.64 ± 0.03

Values denote mean ± standard error (n = 3). CON = contaminated group; UNCON: uncontaminated group; C = Centro, S = *S. stenocarpa*; M = *Mucuna*; M with S = *Mucuna* intercropped with S, S with M = *S. stenocarpa* intercropped with M; C with S = Centro intercropped with S; S with C = *S. stenocarpa* intercropped with Centro; 12WAG = 12 weeks after germination.

Table 4. Physiochemistry of the soil used in this experiment.

S/N	Parameter	Amount
1	pH	7.04
2	NO_3 (mg/kg)	4055.00
3	SO_4 (mg/kg)	1725.00
4	PO_4 (mg/kg)	13.90
5	% Total Nitrogen	0.34
6	Cl^- (mg/kg)	70.00
7	% TOM	6.00
8	% TOC	3.49
9	Mg (mg/kg)	215.00
10	Na (mg/kg)	112.00
11	Cd (mg/kg)	11.60
12	Cu (mg/kg)	45.00
13	Fe (mg/kg)	18690.00
14	Conductivity (µs)	12.00
15	K (mg/kg)	5.30
16	Ca (mg/kg)	516.00
17	PAHs	< 0.001
18	BTEX	< 0.001

especially in low-till systems, thereby reducing application rates of synthetic herbicide owing to the expressed allelopathy. Nutrient biostimulation could be explored for augumentation in this practice. From the foregoing, allelochemistry may also enlist Mucuna for herbicide development. Generally, allelopathic Mucuna, evident in suppressed growth of weed and *S. stenocarpa* intercropped with it by growth indices analysis, as compared with such interaction between Centro and *S. stenocarpa*, could be explored in agronomic management practice and the response to oil stress further supported expressed allelopathy.

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